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SILICON ON INSULATOR BY WAFER BONDING

AVESH GARG[1]*, ANURAG SINGH[1] AND NITIN GUPTA[2]

[1]Electronics and communication department, Ambala College of Engineering and Applied Research Devsthali, Ambala, India
[2]Applied Science Department, Advance College of Technology and Management Palwal, Haryana, India
*Corresponding Author: Email- aveshgarg@gmail.com

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Abstract- Silicon wafer bonding has become the cornerstone technology in MEMS manufacturing. Several aspects of silicon on insulator technique utilizing bonding of oxidized silicon wafers are investigated in this work. The bonding is achieved by heating a pair of wafers in contact with each other, in an inert atmosphere. The bond strength increases with the increase in bonding temperature. Potential applications of this technique, already demonstrated in research labs, range from high performance SOI CMOS circuits and high voltage or power devices to on-chip micro sensors and integration of III–V materials with Si substrates.

Keywords- CMOS, MEMS, SiO_2, SOI, HF

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Introduction

Silicon on insulator bonding without any glue layer has been known for more than quarter of a century. The major problem faced in field assisted technique is the need of electrical contacts to wafer at high temperature. The wafer bonding technique discussed in this paper is the method used to remove the problems of field assisted method. In the wafer bonding technique an oxidized Si wafer is bonded to other Si wafer with the help of hydrophilic bonding. The general process of wafer bonding can be summarized as a three-step sequence: surface preparation, contacting, and annealing. The first step is important because the quality of the bond has a strong dependence on surface conditions. Precautions are therefore taken to ensure that there is no surface contamination or particles that could preclude a good bond. A 1 µm particle, for instance, can cause a void as large as 1 cm in diameter. Once the samples have achieved an appropriate level of cleanliness they are brought in contact to initiate the bonding. Close contact is ensured by pressing them together. In the case of silicon direct wafer bonding, a high-temperature step is subsequently performed to strengthen the bond. SOI is an extremely versatile starting material for fabricating micromechanical systems both with and without the inclusion of silicon integrated circuits on a shared substrate. Applications include pressure sensors [1], improved dielectric isolation [2], CMOS transistors [3] and SRAM [4]. In this paper we presented various aspects of SOI bonding. In this paper we will study about the silicon on insulator bonding by wafer bonding. In the next section we will study about the experimental procedure we followed for SOI bonding. After that in the next section we will study about results and discuss the results obtained by this process.

Experimental

The bonding between two wafers can be achieved only if two surfaces are clean and smooth. So firstly the wafers taken are cleaned by PIRANAH cleaning method. In this cleaning we prepared a solution of H_2SO_4:H_2O_2 in the ratio 1:3 (SPM, H_2SO_4/H_2O_2

@110- 130°C). After PIRANAH cleaning wafers are dipped in hot water three times followed by a ultrasonic bath. This step is done to remove the contaminations from the wafer. Then boiling HNO3 is prepared and wafers are dipped in this solution. After 15 minutes, of this dip, the wafers are loaded into the oxidation furnace for oxidation. Temperature of furnace is kept at 1100°C and oxygen is passed through it. After 2 hours of oxidation, the wafers are allowed to cool down slowly. One wafer is now put in the HF solution to have the de oxidation of wafer. Now the deoxidized wafer is again cleaned by PIRANAH cleaning. After cleaning the wafer a water dip is given to both the wafers to have the hydrophilic action. Now the polished surfaces of two wafers are kept in contact with one another and wafers are pressed gently against one another to avoid voids due to air trapped in-between the two wafers. Now the room temperature bonding occurs between them. After that wafers are placed in an oven at 200°C for two hours. After two hours annealing is done at 800°C in inert environment for 2 hours

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Result and Discussion

A. Room Temperature Bonding

Two flat surface, smooth, hydrophilic surfaces are bonded at room temperature without any external force. The bonding forces are believed to be caused by attraction between hydroxyl group (-OH) [5] and possibly some water molecules absorbed on the two surfaces. The attraction is strong enough to cause the spontaneous formation of hydrogen bonds across the gap between two wafers. Once initiated, these bonding processes spread throughout the entire area between the two surfaces. The hydroxyl groups are usually attached to the surface through the reaction of a clean surface oxide with the moisture from the surroundings.

B. Effect of annealing

Bonding starts to happen on room temperature, but its strength is increased by annealing at temperature> 800°C [6]. The bond strength increases monotonically with temperature and exhibits three distinct phases. The first phase, hydrogen bonding between hydroxyl group (-OH) on one surface with the oxygen atoms of either the SiO_2 or OH group on the other, begins at room temperature and starts being replaced by the second phase, the Si-O-Si bond, around 200°C.

This phase involves elastic deformation of wafers in locally unbounded micro areas and dominated through temperature up to about 1100°C. Finally in the third phase, viscous flow of oxide around and above 1100°C leads to complete bonding. However annealing in oxygen gives bonds superior to the annealing in the presence of nitrogen. The figure-1 shows bond strengths measured for the oxidized wafers contacted in air and bonded in dry oxygen or nitrogen respectively [6]. The bonding in the wafers occurred successfully and found to have a good bonding strength. However the bonding strength of the SOI bonding can be obtained by the HF method which is explained below.

C. Characterization

The method of characterization used is HF test. This bond strength measurement method is based on silicon dioxide etching in hydrofluoric acid (HF). The HF etch rate is dependent on the bonded interface quality. In this method the sample is dipped into the 50% hydrofluoric acid for 10 minutes and the etched distance is measured with scanning electron microscopy from cross-sectional samples. For high temperature bonding of hydrophilic silicon wafers, the relation between bond strength and etch rate is logarithmic, as shown in the Fig 2. Therefore by calculating the etched distance the surface bonding energy can be easily calculated.

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